# Sensor Aided Automatic Path Finding Wheelchair

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***Abstract***— **A conventional motorized wheelchair has been fitted with sensors and programmed with an intelligent guidance system to efficiently maneuver itself automatically from one point to another in a facility equipped with a grid of sensors that provide the wheelchair with the basic map of its course. The device described in this paper has been conceptualized such that once the wheelchair is given information regarding the starting and stopping point in a controlled facility, the wheelchair with this pre programmed information can efficiently construct a path towards its destination and automatically drive to that point from its present position while avoiding obstacles in its path and negotiating any turns and bends that it encounters in its course. This is achieved by means of sensors (IR and sonic) located at strategic points on the chair, circuits that control the speed of the motors, and a set of microcontrollers programmed to execute the different functions of the wheelchair. The facility in which the wheelchair works is fitted with a set of sensors that form the basis of the network which is used by the program governing the wheelchair's automated movement to provide guidance to it by means of a course map.**

***Index Terms***— **wheelchair, automatic, motorized, sensor aided, path finding**

## I. Introduction

A wheelchair is a chair with wheels, designed to be a replacement for walking, which can be propelled manually and also driven by motors. Wheelchairs are used by people for whom walking is difficult or impossible due to illness (physiological or physical), injury, or disability. Medically a loss of mobility can be broadly attributed to two reasons- Musculoskeletal disorders such as paralysis, paresis, ataxia, fibromyalgia, etc and neuropsychiatric disorders such as posttraumatic stress disorder, cognitive dysfunction etc. Motorized wheelchairs have gone through enormous modifications and technological enhancements over the last few decades. Over the years scientists have developed various kinds of motorized-wheelchairs, some are verbally controlled by the user, where verbal instruction from the occupant maneuvers the wheelchair [1], while some are guided by the user's mind [2]. The most widely available ones have onboard computer to process all operations [3]. Most of these motorized-wheelchairs available in market need human intervention to guide the chair. Either the user uses steering/handle to maneuver the chair or uses digital/ computer controls [4] to do the same. But for the people who are very old and hence unable to move their limbs systematically to guide the chair along the desired direction or people who due to illness would fail to do so, these motorized wheelchairs do not suffice their requirements efficiently. Hence, our endeavor in this paper was to make such a system that will overcome this impediment effectively and can help the old and ailing or the injured to find their way from their present location to a given destination within a given closed system with minimal human interference. In the case, once the user sets the chair's present location and the desired destination onto the system, the chair with the help of a unique sensor-aided automatic path-finding algorithm finds its way through all turns and avoids collision to eventually reach the destination successfully. Unlike the other multi-featured [5] motorized-wheelchairs [6] this system uses an effective but simplistic design and simple mechanical and electronic components and hence is largely affordable to all people, thus providing mobility-aid to all.

## II. Design of the Sensor Aided Automatic Path Finding Wheelchair

The device that has been designed is a Sensor Aided Automatic Path Finding Wheelchair.

In brief it is a motorized wheelchair designed to carry one occupant at a time. It can move on its own and requires no assistance for steering from the occupant of the wheelchair or from any outside individual. The only user-side communication required is the information regarding the starting and stopping points of its course. Using the supplied information it arrives at a decision upon the path to take in order to complete its journey. Additionally, it is designed to detect and avoid obstructions in its path.

### A. The System in Brief

Since this is a motorized wheelchair whose locomotion is automatic and the course that it takes is decided by the programming that governs the movement of the chair, the entire device can be described as consisting of the sections shown by Fig. 1.

The three parts have been taken up individually in the following sections:

1. The Wheelchair

The design of the wheelchair has been shown in Fig. 2. It consists of the following parts:

*The Seat*: This is the seat of the wheelchair where the occupant sits.

*The Backrest*: This is the backrest of the wheelchair.


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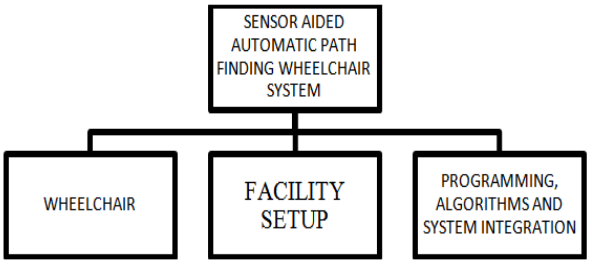


Figure 1. Block Diagram showing sections of the sensor aided automatic path finding wheelchair system

Primary Wheels: A pair of large wheels on either side. of the chair that are primarily responsible for movement.

Secondary Wheels: A pair of secondary wheels that are responsible for changing the orientation and directing the movement of the chair.

Sensor Panels: Panels fitted with IR and sonic sensors that help in the movement of the wheelchair.

Panel 1: This is the top most panel located above the head of the passenger and consists of a set of sensors used to detect and avoid collision.

Panel 2: This is the middle most panel located at the waist region of the passenger and consists of a set of sensors used to detect and avoid collision

Panel 3: This is the 3rd panel located below Panel 2 at the footboard of the chair and consists of a set of sensors used to detect and avoid collision.

Panel 4: This is the bottom most panel consisting of the sensors that help the chair to deduce its position in the facility while moving.

Panels 5 and 6: Located on either side of the wheelchair and used in aiding its locomotion

Main Circuit and Motor Box: This box houses the motors, their concerned circuits, the microcontrollers and mother board, the memory devices and other electronic circuits used to assist the movement of the wheelchair [7].

User Interface: A screen and a keypad used to put in course related information into the wheelchair.

The Microcontroller PIC18F252: This microcontroller is ideal for our purpose because of its enhanced flash

which will be useful in processing the inputs from sensors and other peripherals. It also has 23 I/O lines to further assist the entire process. It has 1536 bytes of RAM which is again suitable for this system. There are several other microcontrollers of similar specifications are available of different makes which can also be applied.

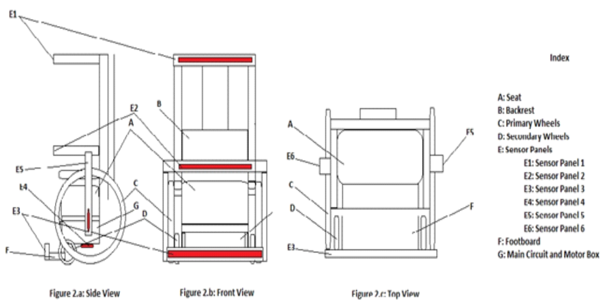


Figure 2. The design of the wheelchair

2. The Facility Setup

Since the movements of the wheelchair are automated, it requires a guidance system to govern its movement to its destination from its starting point with efficiency and accuracy.

In order to achieve this inside a closed facility, a guidance system has been constructed since common mapping technology like the GPS cannot function efficiently within a concise region.

The entire facility has been broken up into a number of small points named “Bases” . The bases are the places at which the wheelchair can stop or commence its locomotion. The wheelchair cannot stop (except upon encountering an obstacle) in the region between two successive bases under normal circumstances. It can move from one base to the next, i.e. in other words its movement has been quantized between the different bases. The bases are designated by IR emitters embedded on the walls of the facility and that once switched on emit a steady beam of IR from them towards the other wall. Each base emits an IR beam with a different wavelength and no two are the same.

3. Programming, Algorithm and System Integration

The following section describes how the wheelchair and the facility setup are integrated to make the system perform successfully:

Upon seating a passenger in the wheelchair, the following information are fed in to the chair through the User Interface –

a. the present position of the wheelchair and
b. the destination of the wheelchair .

The present position of the wheelchair will always be the Base number of the base that it has last crossed.

The destination of the wheelchair will always be the Base number of the base that it has to reach.

Once the data has been punched in, the wheelchair commences its movement forward.

For a safe journey, the wheelchair can accelerate at 0.14 $m/s^2$ and can achieve a constant speed of 0.73152m/s in 5s. This is similar to the statistics of a wheelchair pushed by hand.

As it moves forward, it moves over the IR emitters of each base. Only when it detects the IR emitter corresponding to its destination, it decelerates to a halt.

The details of the working of the wheelchair have been described in the following section.

### *B. Base-Wheelchair Interaction*

The base point IR emitters continuously emit an IR beam in wall-to-wall direction, i.e. cutting through the line of movement of the chair.

The Base Detection circuit of the wheelchair consists of the blocks shown in Fig. 3.


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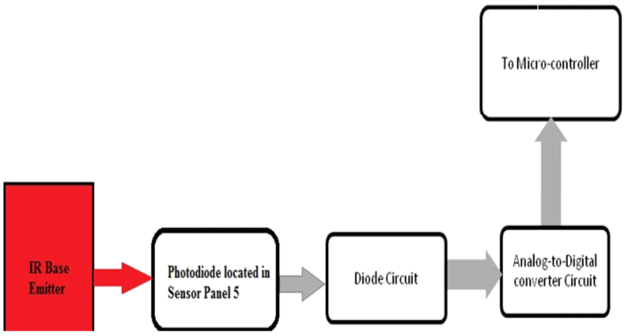



Figure 3. Base Wheelchair Interaction

As soon as the wheelchair crosses the Base with Base number (say) 6, either (or both) of the Sensor Panel 5 or 6 located at the sides of the chair crosses directly across the IR emitter of the base and the IR beams strikes the photodiode. The photodiode produces a voltage signal by photovoltaic effect particular to the wavelength of the emitter. This signal is processed through an ADC circuit and is converted to the binary value 110 corresponding to the base number 6. This value is fed to the microcontroller. A program is run by the microcontroller to compare this number with the number corresponding to the destination point punched in at the time of initiating the journey. Upon detection of a match, the MC instructs the chair to decelerate to a halt. Otherwise, the chair moves forward. Since each base has a unique number identifying it, the IR wavelengths of the corresponding emitters should be uniquely determined by this base number.

For this system, the UPD-300 IR 1 photodiode from Alphalas GmbH Company or a photodiode of similar capability can be utilized. This photodiode has a response time of less than 1ns. Considering the constant travel speed of the wheelchair to be somewhere around 0.73152 m/s and considering the size of the IR emitter to be of a diameter of 0.12m approximately, the response time of the UPD-300 IR 1 is sufficient to detect the base. Additionally, the processing of the detected signal and corresponding notification for the deceleration to begin takes approximately a few more nanoseconds using high-end MPUs [7]. This means that the chair motor will be almost instantly notified of a halt once it goes over the base, if required.

Once it is detected that the base number matches the destination base number, the motor is cut off and brakes are applied. Considering the wheelchair to be moving at a rather slow speed of about 0.73152 m/s or it will require about 4 seconds and 0.6m for the chair to come to a complete stop with a deceleration of 0.18m/s$^2$.

### C. Locomotion of the wheelchair

Upon commencement of the journey, the wheelchair moves forward. It acts otherwise only when it encounters an obstruction in its path.

It is possible for the wheelchair to negotiate bends and turns by the following procedure.

Let the wheelchair be negotiating a 90° right turn as shown in Fig. 4. When it was moving forward, it was steadily approaching Wall A. At the same time the sensors in Panels 5 and 6 kept track of the walls on either side of the chair. For the chair to encounter a turn, it must come face to face with a wall like that shown by Wall A detected by Obstruction Detector (OD). At the same time there is usually a wall on one of its sides like that shown by Wall B. Here walls A and B form the corner of the bend. The wall on the other side (Wall C) ends at a certain point and bends to the right.

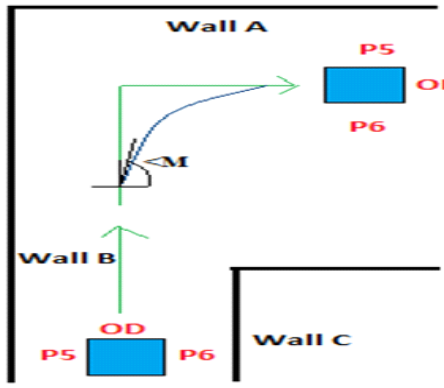



Figure 4. Illustration of a 90 degrees right turn

Hence, the wheelchair will negotiate the bend and perform a turn by the following table (Table 1).

### D. Collision avoidance

The wheelchair avoids a collision in its path and safely steers the passenger towards the destination by the following means:

Obstructions in the path are detected by means of the three panels of sensors Panels 1, 2 and 3.

It is obvious that the wheelchair can avoid the collisions that Panels 2 and 3 can detect but not the ones that are detected only by Panel 1 since it cannot duck under them.

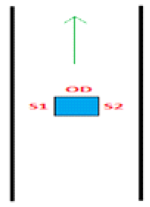
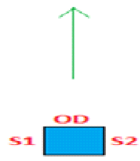
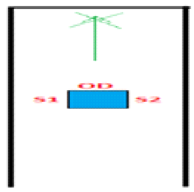
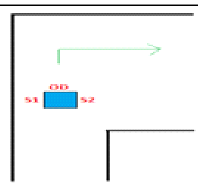
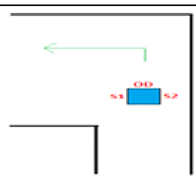
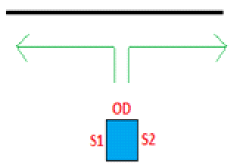
In such a case it comes to a halt and sends a message to the control centre informing of the situation.

Additionally, if all the three panels pick up the obstructions simultaneously, then the obstruction may be a wall or a human being standing in front of the chair. In such a case, it will sound a horn and wait for a certain period of time. If the obstruction does not move away (such a case as when the obstruction is a man) the chair notes it to be a wall and moves according to its bend negotiating algorithm.

If the obstruction is determined by computation to be of a size navigable by the chair, the chair executes a collision avoidance method [8] to move past it.

The path-finding algorithm of the wheelchair has to work in conjunction with an effective collision avoidance system in order to negotiate with obstructions on its way. Sabyasachi Ghoshray and K.K. Yen worked in this very field in their paper titled “A Comprehensive Robot Collision Avoidance Scheme by Two-dimensional Geometric Modeling”. This concept is very appropriate and readily applicable in our system.

TABLE I.
WHEELCHAIR BEND-TURNING CONDITIONS

| Obstruction Sensor Detection | Side Wall Sensor 1 Detection | Side Wall Sensor 2 Detection | Movement | Diagram |
|---|---|---|---|---|
| No | Yes | Yes | Forward |  |
| No | No | No | Forward |  |
| Yes | Yes | Yes | Forward till obstruction proximity is reached then halt |  |
| Yes | Yes | No | Turn to wall side not being sensed by Sensor 2 |  |
| Yes | No | Yes | Turn to wall side not being sensed by Sensor 1 |  |
| Yes | No | No | Turn either way according to pre programmed directions |  |

Accordingly, the panels have been made wider than the width of the chair (taking into account the wheels) so that the peripheral sensors can make full use of their position and perform collision avoidance with full efficiency as shown in Fig. 5.

The sensors used for detecting collision are of the Ultrasonic type. The Ultrasonic Range Finder SRF08 is an ultrasonic sensor that has a detection range of 1" – 18’. Let the safe distance for the chair to turn or come to a stop be about 1.2 m.

Then it has 4.27m to decelerate and travel over before reaching this point. Decelerating at a safe 0.06m/s$^2$, it will take 11.7s to come to a stop.

### *E. Map Construction*

Previously, ferrite marker lines laid on the ground have aided the movement of manually controlled semi-automatic wheelchairs [9]. The wheelchair being described in this paper is just provided with the starting point base number and the destination point base number.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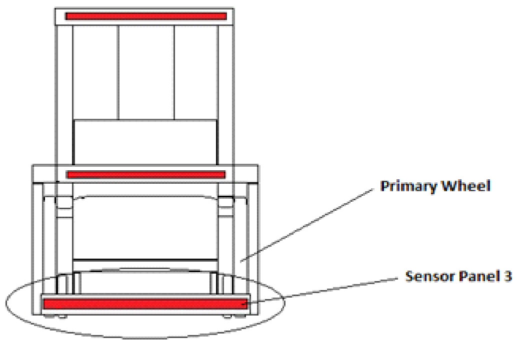


Figure 5. Sensor Panel Width

Using these two pieces of information and the map of the floor of the facility in which it operates, it generates a path between these two points and makes a list of the base numbers in between the starting and destination point base numbers. These numbers are stored in an array and are popped out one by one as the chair travels over them. This method also allows the chair to correct its course if it strays. For that action, the chair keeps a list of the turns it performs in a separate array. When it comes over a base point that it should not have crossed in its path, i.e. it has gone off course, it retraces its path to the last turn and takes the turn in the opposite direction, thereby rectifying its course.

The algorithm for constructing the path between the two points is given below:

The links between two base points are allocated a particular value (a weight) preferably the distance or the shortest distance between the two points. Each of these values is pre-stored in the memory of the wheelchair's computer. Using these values, the chair is able to calculate the most efficient route between two points as follows:

A list of links made up by the base points immediately following the source point (present position base point) is made.

If the destination base point is not one of them, then a sub list is made with the links between the last base points and their immediately following base points.

This continues until one of the base points in the list is the destination point.

If the destination point occurs twice in one end list, then the path with the smallest cumulative weight value is chosen.

Example: The map of base points shown in Fig. 6 is considered. Let the source and base points be A and 10 respectively. The path is constructed as follows:

Map Construction

List 1: AB = 5, AD = 8

Sub-list 1: BC = 3, DC = 10

Final Path: A-B-C (since AB + BC (= 8) < AD + DC (=18)

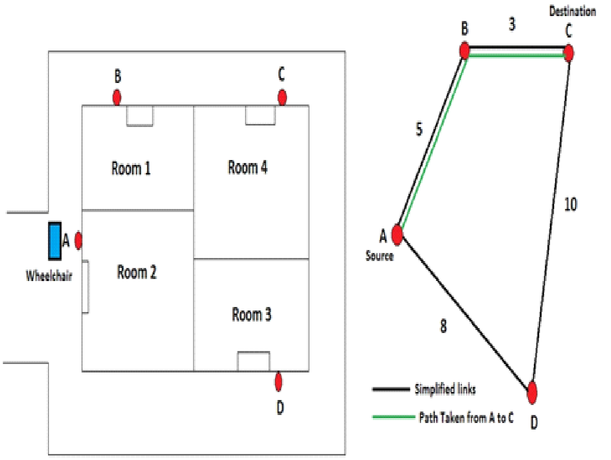


Figure 6. Map Construction

The wheelchair can thus store the base point IDs in the sequence A-B-C and thus keep popping them one after the other as it crosses them and come to a halt once it pops C.

The wheelchair will also decide upon which direction to move initially so that it does not travel excessive erroneous distances (i.e. according to the above example, moving right from A, towards D even after constructing the correct path because of it initially facing right from A) by the following method:

The base point sensors located on either walls or on one wall as mentioned before have two parts as shown in Fig. 7. These two parts emit two unique signals that the IR receptors in the Panels 5 and 6 of the chair pick up. Owing to the fact that the IR bases are a bit elongated and the command processing take a few nanoseconds with the chair moving very slowly at the onset of the journey, the chair is capable of picking up either of these two signals.

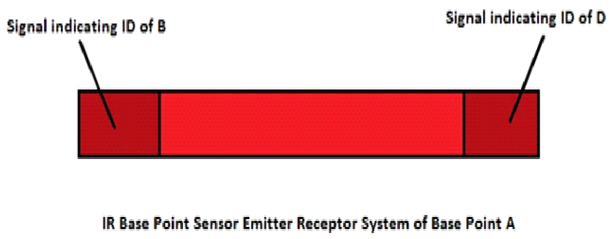


Figure 7. Directional Indicators in the Base Points


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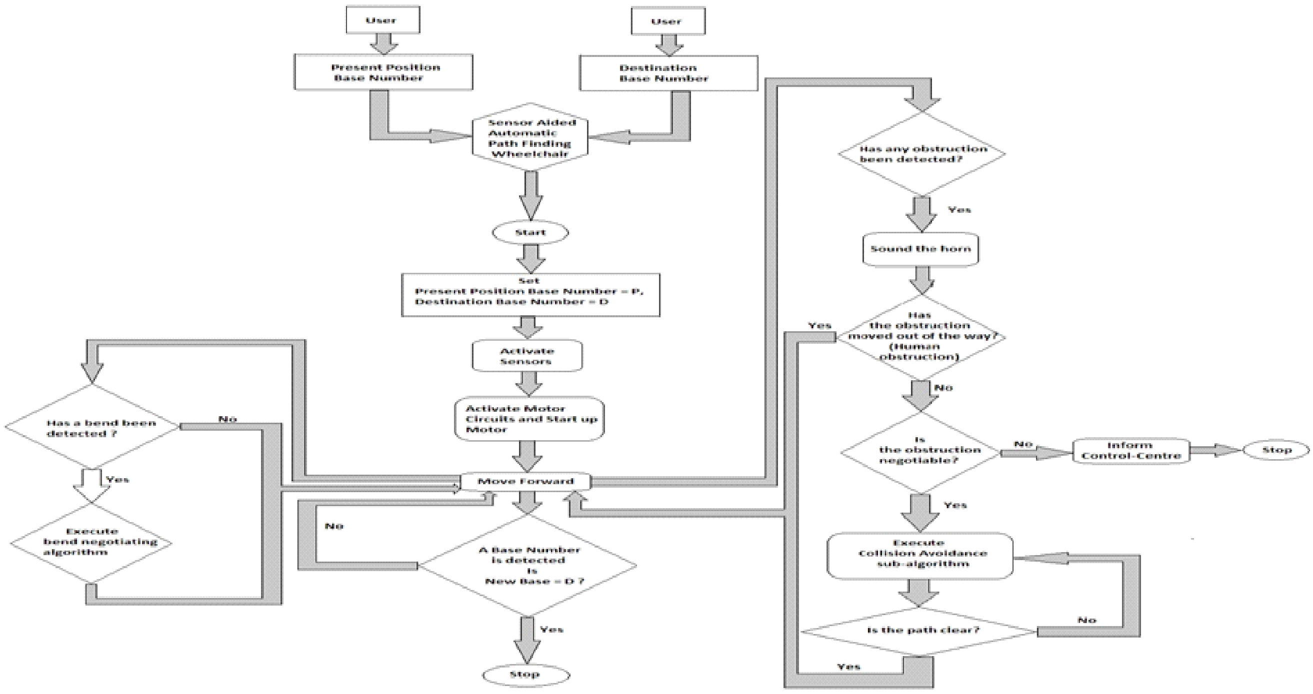


The interpretation of the signals by the chair, give it the base IDs of the immediately next base and it can judge whether the course it has set is correct or not. In that way, according to the above example, even if it starts moving towards D initially, once it gets notified of this, it turns around and moves towards C.

### *F. The Master Algorithm*

The Master Algorithm responsible for the automatic locomotion of the wheelchair is given below in Fig. 8.

## III. Discussions

This motorized wheelchair needs minimal human intervention unlike its predecessors. It does not need any human guidance to find its way from the starting point to the destination set initially by the user. Basic electronic and mechanical component and devices have been used in the making which makes it suitable for large-scale industrial production. Its simplistic design and optimized utilization of all its components effectively makes it a lot cheaper than other similar motor-driven wheelchairs and hence it will be affordable to all. This system has immense leverage for further enhancements and modifications.

## Conclusions

The paper has successfully conceptualized the wheelchair and with the help theoretical analysis and diagrammatic system representation has also proved the efficient working of the entire machine under practical of realizable circumstances. This machine, unlike its predecessors, need minimal human guidance during its state of mobility and is a lot more affordable to people due to its simplistic yet highly effective and scientifically realizable structural design which makes it suitable for ndustrial production as well. This machine has immense opportunitiesfurther modification and enhancements. This wheelchair can be readily implemented inside closed systems likehospitals, rehabilitation centers or other facilities and hence will be highly helpful for sick people.

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